NEED FOR EXPANDED ENVIRONMENTAL MEASUREMENT CAPABILITIES IN GEOSYNCHRONOUS EARTH ORBIT

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ABSTRACT

The proliferation of environmental measurement satellites in low altitude earth orbit (LEO) has demonstrated the usefulness of earth remote sensing from space. As use of the technology grows, the limitations of LEO missions become more apparent. Many inadequacies can be met by remote sensing from geosynchronous earth orbits (GEO) that can provide high temporal resolution, consistent viewing of specific earth targets, long sensing dwell times with varying sun angles, stereographic coverage, and correlative measurements with ground and LEO observations. An environmental platform in GEO is being studied by the National Aeronautics and Space Administration (NASA). Small research satellite missions in GEO were studied (1990) at NASA's Goddard Space Flight Center (GSFC). Some recent independent assessments of NASA earth science space programs recommend accelerating the earlier deployment of smaller missions.

CURRENT REMOTE SENSING CAPABILITIES

Truly a benefit to all mankind, remote sensing has provided new environmental information, timely data from space, and worldwide coverage quickly and inexpensively – a "new way to see". It has helped individuals, private industry, regions, continents, and the entire world to more rapidly advance technologically in the earth sciences and to enjoy the resultant benefits.

Since the early 1960s the entire world has been served by an international array of meteorological satellites that continues to provide and efficiently disseminate remotely sensed weather data. The present Landsat earth observing satellites with a land and ocean measurement focus began with the NASA Earth Resources Technology Satellite (ERTS) in 1972.

NASA research in remote sensing has resulted in a number of research and operational prototype missions such as the Television Infrared Operational Satellite (TIROS), the Synchronous Meteorological Satellite (SMS), and ERTS. Some of these early programs have matured into fully operational systems currently in use worldwide. Examples are the Earth Observation Satellite Company (EOSAT) series of Landsats and the National Oceanic and Atmospheric Administration's (NOAA) polar orbiting and geostationary series of meteorological satellites.

The French Systeme Probatoire d'Observation de la Terre (SPOT) system represents one of several successful or developing foreign space remote sensing missions. The USSR, Japan, India, the European Space Agency (ESA), and the Peoples Republic of China either are developing or have mature earth observing space systems in place.

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The technology has proven of great benefit in many disciplines including agriculture, land use and mapping, forestry and range resources, hydrology and water resources, oceanography and marine resources, geology, and the atmospheric sciences. ERTS, its Landsat successors, and the NASA experimental and NOAA operational meteorological satellites have contributed to detection, monitoring, and mapping of numerous environmental phenomena such as forest fires, geologic faults and earthquake damage, volcanic eruptions, crop and forest diseases and drought effects, coastal and inland floods, ocean ice formations and their motions, snow melt, and land use changes. Ground stations to directly receive Landsat and other earth sciences space data have been built in the U.S., Brazil, and over a dozen other countries worldwide.

NEED FOR IMPROVED SPACE REMOTE SENSING CAPABILITIES

But, as the usefulness of remote sensing from space becomes clearly identified, very distinct requirements for additional remote sensing capability are emerging. Because most environmental space measurements (except for meteorological data from GEO satellite sensors) are derived from LEO missions (eg., Landsat, SPOT), with brief viewing times and days or weeks before targets appear in view again, there is a definite need for space mission characteristics such as higher temporal resolutions, more consistent viewing of specific earth locations, longer sensing dwell times with varying sun angles, correlative GEO and other (e.g., LEO, earth surface) measurements, and continuous stereographic coverage.

Many U.S. and international officials, agencies, and organizations have translated desires for improved environmental measurement capabilities from space and other sources into recommendations and specific programs. The NASA Advisory Council Earth System Sciences Committee recommended a number of NASA, NASA/NOAA, or joint international earth observing programs, missions, and instruments in its *Earth System Science – A Closer View* (1988). Included in the list are a Landsat 7 ocean color scanner referred to as SeaWIFS (Sea Wide Field Sensor), an atmospheric carbon monoxide monitor, Space Shuttle earth pointing imagers, microwave imager/sounders, scanning radar altimeters, and a moderate resolution imaging spectrometer (MODIS) to measure radiances of land, ocean, and atmospheric parameters. The committee placed special emphasis on remote sensing from geosynchronous earth orbits.

In 1987, Dr. Sally Ride of NASA was commissioned to head a task group "..charged with defining U.S. space initiatives..." The task group presented a report entitled *Leadership and America's Future in Space* to the NASA Administrator. It defined Mission to Planet Earth (MPE), as "...a program using the perspective afforded from space to study and characterize earth on a global scale." The MPE initiative is also related to the U.S. earth system science program and the broader international geosphere – biosphere program as well as the Global Change Measurements System Program. Remote sensing is an integral part of all these programs. Operational and research missions in LEO and GEO are specifically identified.

Scientists representing a diverse group of federal agencies, universities, the ESA, Japan's NASDA, and several NASA Centers have defined a strong need for a science research earth observing system in GEO to study geophysical processes ranging from land use to oceans, volcanos, hydrological cycles, tropical systems, atmospheric processes, and more. These scientists are members of a Geostationary Platform Earth Science Steering Committee (GPESSC) formed in 1987 by NASA.

SMALL RESEARCH MISSIONS IN GEO

The feasibility of a precursor GEO mission to the earth observing geoplatform has prompted an informal internal study within NASA's Goddard Space Flight Center of a relatively small earth science research mission, that could be launched about 2000 *(Geosynchronous Environmental Missions,* 1990). It would time phase with the EOS, the Tropical Rain Measurement Mission (TRMM), the Total Ozone Mapping Spectrometer (TOMS), and other earth observing missions that are part of the MPE initiative. The proposed mission could serve as a precursor to the geoplatform and be used as a test bed for new research instruments either in terms of technological performance or scientific usefulness of the data. If launched, it would be the first total research mission in GEO in over two decades and the first ever accomplishing land, oceanic, and atmospheric research simultaneously from that orbit.

Escalating Support for Less Complex Space Systems

Although the geoplatforms are expected to become the major international earth observing systems in GEO, recent developments reflect some support for an earlier, smaller, presumably more reliable, space mission. For example, elsewhere in his remarks to AAS on January 10, 1990, Vice President Quayle expressed his and the National Space Council's concerns "...over the time it takes to translate promising ideas into real space capabilities." He explained that "...our programs seem to be taking too long and costing too much to build," resulting in a loss of space leadership. He also asked that NASA look for new and better approaches and innovatively use existing technologies for space exploration. But despite this counsel, in the 1990 President's budget, the $50 billion allocated for the Global Change Program did include the EOS program but not geoplatforms, possibly postponing a "new start" for this GEO mission to about 1995.

In the *Summary and Principal Recommendations of the Advisory Committee on the Future of the U.S. Space Program* (1990), reference was made to criticism stemming from concerns over the complexity of major NASA space projects. An American Institute of Aeronautics and Astronautics (AIAA) review panel and other industry and NASA officials have advocated (1990) the use of smaller satellite systems in lieu of larger ones in the interest of schedule, cost, and reliability impacts.

Mission Objectives

The principal objective of the mission is to provide one or more minimum lead time, state–of–the–art research missions in the 1990's to satisfy earth science (land, ocean, atmosphere) needs for improved sensing capabilities in GEO. A second objective is to respond to recent Administration recommendations for less expensive, shorter lead time, and more frequent science missions.

Its purpose is to continue advancing knowledge of the earth sciences in concert with goals of the MPE initiative in a time frame that fills a growing gap between prior geosynchronous environmental research missions and the first geoplatform. The spacecraft can be moved to worldwide longitudes to investigate global atmospheric, land, and oceanic processes of current interest. Thus, the proposed mission can be utilized by earth scientists worldwide for research purposes to help assess or define requirements, not only for future remote sensing space systems, but also for more immediate land use, environmental planning, and associated actions by local, federal, and international agencies. The mission could also serve as a protoflight for operational land, ocean, or meteorological instruments and sensors prior to in–line development on future GOES or similar systems.

Mission Summary

The mission would include one or perhaps two instrumented spacecraft with associated ground based command and data acquisition terminals, data processing equipment, and a data storage and dissemination network. The system expects to utilize current spacecraft designs, already under development by leading U.S. manufacturers for other space purposes, to reduce non–recurring costs, and, hopefully, increase reliability and accelerate schedules.

The instruments under consideration are:

(1) Microwave sounder/imager (initial 3.4m diameter antenna);
(2) Visible/infrared imager;
(3) Infrared sounders:
  (a) earth scanning (Michelson interferometer and Fabry–Perot), and
  (b) limb scanning (Fabry–Perot);
(4) Ozone mapper;
(5) Lightning mapper;
(6) Solar sensors:
  (a) active cavity radiometer irradiance monitor (ACRIM),
  (b) solar spectrometer, and
  (c) solar disk sextant (SDS);
(7) Information relay systems:
  (a) Data collection system (DCS), and
  (b) Search and rescue system (S&R).

The total weight of the instruments listed above is estimated at approximately 600kg per flight with two flights contemplated, making launch on an Atlas IIAS vehicle or equivalent possible.

The various types of research planned (land, oceans, atmosphere) will probably require continuous data acquisition and transmission most of the time from various equatorial longitudes. There may be heavy usage periods when data are desired full time from on–board instruments simultaneously with data from ground based sensors transmitted through the on–board DCS.

CONCLUSIONS

A need for expanded remote sensing environmental capabilities is shown based on scientific, NASA U.S., and international assessments, programs, and recommendations. The NASA geoplatform, currently under development, will result in a quantum jump in providing improved earth science measurements from GEO. An internal pre–Phase–A study completed in 1990 at NASA's GSFC, proposes utilizing existing spacecraft designs, a modest complement of new or modified sensors, and state–of–the–art launch vehicles to provide an earlier research protoflight capability in GEO should it be needed as a research gap filler or as a precursor to the geoplatform. Based on some recent recommendations for smaller, less, complex, and more frequent environmental space flights, a Phase–A study is certainly recommended for the smaller research mission to determine if it is indeed a feasible concept.

Vice President Quayle's remarks to the American Astronomical Society (AAS) on January 10, 1990, in Arlington, Virginia, reaffirmed the nation's commitment to the MPE initiative. He pointed out that "...environmental concerns are a top priority of people everywhere..." and that "...space can give us the means to understand the problems and devise solutions." He added that evidence of environmental concern is everywhere today. Prominently publicized in the news media are reports of phenomena such as depletion of the ozone layer and its influence on the greenhouse effect, the effects of alteration or depletion of tropical rain forests on global climate, and variations of vegetation coverage that affect the cycling of chemicals controlling the quality of air we breathe and food production.

Further underscoring the long range aspects of earth remote sensing from space, in the national budget prepared by President Bush and submitted to the U.S. Congress in February, 1990, NASA was allocated approximately $50 billion over 20 years for its Global Change Program.

ROLE OF GEO AND LEO MISSIONS IN IMPROVING REMOTE SENSING

Some techniques for meeting remote sensing needs have already been implemented. Weather and earth observing satellites have grown in size to accommodate more and better sensors to provide greater spatial resolution and to enable additional measurements that are of value as individual and combined data sources in correlation with other measurements acquired from space or *in-situ* data collection platforms or other ground facilities.

The NOAA Geostationary Operational Environmental Satellites (GOES) are undergoing a change from spinning spacecraft to the GOES I–M series of three–axis stabilized spacecraft to increase observational dwell times and achieve other improvements. GOES–N, currently in the preliminary system design phase of development, is expected to satisfy many but not all of the 1989 requirements of the National Weather Service (NWS) specifically and NOAA in general. NOAA weather satellites in LEO are also being improved continuously with a Phase–A study for NOAA O, P, Q now in process at GSFC.

To meet other evolving land and ocean observational requirements, dual Landsat satellites in orbit simultaneously provide repeat imagery once every 8–9 days instead of the 16–18 day coverage available with only one in space. The spatial resolution of the imagers has also progressed from 80 meters in the 1970s to better than 30 meters. Spectral band ranges have been expanded to include the thermal infrared, thereby providing additional information not previously obtainable from that series. (The NOAA and NASA meteorological satellites have carried thermal infrared sensors for years.) The French SPOT earth observing satellite has the capability of obtaining stereoscopic images of the earth's surface, which has opened a new frontier in remote sensing technology.

NASA is currently developing some missions designed to meet broad emerging needs of various earth science disciplines. Listed below are several of the agency's major programs now in some phase of development or under consideration. The missions are mostly pure research, but in many cases the research will be applicable to future generation operational remote sensing systems in space.

Upper Atmosphere Research Satellite (UARS)
Earth Observing System polar platforms (EOS)
Total Ozone Mapping Spectrometer (TOMS)
Tropical Rain Measurement Mission (TRMM)

France/U.S. Ocean Topography Experiment
Lightning mapper
Geoplatforms
Small research satellites in GEO

The geoplatforms and EOS are being designed to carry facility, research, and operational instrument complements.

BENEFITS OF ENVIRONMENTAL REMOTE SENSING CAPABILITIES FROM GEO

According to the *Geosynchronous Environmental Mission*, (1990), the major emphasis for future GEO satellite system development is expected to be related to:

The Global Change Measurement System program and the U.S. MPE initiative;
Further substantial improvements for storm and mesoscale monitoring;
Ocean and land measurements - particularly those not available from LEO;
Evaluation of fundamental geosynchronous measurement principles; and
A significantly enlarged user community including educational institutions, business, and the general public.

The role of GEO missions in support of this emphasis stems from the unique measurements that can only be obtained from this higher altitude orbit (compared to the polar, sun synchronous orbiting earth observing systems such as the NOAA, Landsats, and SPOTs). According to a GPESSC report (1989), "what cannot adequately be seen from the polar space station (EOS) is the diurnal variability of and dynamical behavior of: precipitation and evaporation, atmospheric water vapor and wind, vegetation color, terrestrial ecosystems–land processes, land–ocean–atmosphere energy fluxes, tropospheric pollutant generation and transport, surface emissivity–albedo–temperature, ocean color–productivity, stratospheric ozone and other trace gases, global warming, coastal processes, soil moisture, and net radiation balance. Varying sun angles are of particular importance to geologists to reveal "...subtle structural details not visible at higher sun angles. Some of these details are almost totally invisible on Landsat imagery..."

The same report lists highly transient phenomena that cannot be observed adequately from LEO such as lightning discharges, volcano initiations, tornadic storms, forest fires, pollution–radioactive episodes, flash floods, phytoplankton blooms, dust storms, and solar storms.

Benefits of improved remote sensing capabilities in GEO are described in the *Geosynchronous Environmental Mission* (1990). They include measurements for improving the understanding and prediction of rapidly evolving meteorological phenomena (e.g., severe local storms, tropical cyclones). In studies of the interaction among sun, earth atmosphere, land, and ocean processes, measurements from GEO are a necessary complement to LEO satellite data, especially for diurnal information (most polar orbiting systems in LEO are sun synchronous, which precludes data acquisition at varying sun angles). General viewing properties from GEO should lead to numerous land and ocean applications and would be a completely new arena for remote sensing, because no sensor specifically designed for land or ocean purposes has ever been flown in GEO. The basic viewing geometry from GEO offers the possibility of high accuracy measurements within 50 degrees latitude of the equator for many earth science parameters. (Note: To preserve their integrity, three subsections below, Atmospheric and

Solar Measurements, Land Process Measurements, and Ocean Measurements, have been extracted virtually intact from the Mission Science Rationale and Objectives chapter of *Geosynchronous Environmental Mission,* (1990), primarily written by W. Esaias, F. Hall, and W. Shenk of GSFC.)

Atmospheric and Solar Measurements

Although the current GOES–7 and planned GOES I–M satellites can measure most parameters in this category, substantial weaknesses remain. Some NWS 1983 meteorological requirements are not expected to be met by the GOES I–M series, and the GOES–N currently under study at GSFC, similarly, may not fully meet NOAA's 1989 requirements. These insufficiencies include:

- Lack of temperature and moisture profiles in cloudy areas;
- Inadequate vertical resolution of profiles in general;
- Insufficient combinations of horizontal and temporal resolutions, radiometric performance, and scene coverage needed in convection monitoring, winds derived from cloud motions, surface temperature, low level moisture estimates; and
- Accurate precipitation mapping.

A lightning mapper, also needed, is under consideration for GOES–N.

New sensors need to be developed to alleviate these inadequacies. It is also important to have selected sensors making simultaneous observations to acquire complete data sets for key parameters.

The advantages of making solar measurements from GEO include: very long periods of uninterrupted observations from GEO, which benefit the separation of differing solar modes in frequency space. (this will aid in the search for solar G modes which have not been definitively found from terrestrial observations); operation from an orbit that infrequently enters the earth's shadow, leading to greater thermal stability of instruments and improved observational capability; and enhanced stability in solar pointing.

Land Process Measurements

Land process interactions are indicated by three coupled feedback loops: a strongly–coupled fast response feedback loop (seconds to days) in which the state of the atmospheric boundary layer (insolation, temperature, humidity, precipitation, and wind speed) modifies the physiological state of surface vegetation. This state, in turn, determines surface albedo, emissivity, and evapotranspiration rates of land surfaces, thereby changing the surface atmospheric state by varying heating and moisture transport rates; a weaker, slower feedback loop (months to centuries) couples the atmosphere (climate) to terrestrial biogeochemical and hydrological cycles and vegetation structure (phenology, height, condition, etc); and a third, even weaker feedback loop (decades to millennia) which couples the climate to the community composition, structure of the terrestrial landscape, and underlying soils.

Over the past few years, NASA has conducted several studies to develop a strategy for studying the earth's biosphere. Three general types of experiments have been defined to better understand the exchange of radiation, heat, and moisture between vegetated land surfaces and the atmosphere, the biodynamics of land–surface vegetation, and the generation and transport into the tropopause of biogenic trace gases.

Coverage of the earth's surface from geosynchronous orbit provides capabilities not available from satellites in either polar sun synchronous or lower inclination orbits for the study of land processes. These are: extended viewing time which permits tracking continuous dynamic processes with the desired viewing frequency, responding to the sudden onset of episodic events, and monitoring events that occur only during certain day or night periods; optimized viewing conditions for a day, several days, or weeks to minimize cloud cover, atmospheric interference, or to fully observe transient phenomena; viewing earth surface targets at any solar illumination angle; and viewing each point on the ground at exactly the same zenith and azimuth angles over time (constant view angle.)

In terms of these unique capabilities of geosynchronous satellites, the first item above is essential for obtaining the remotely sensed parameters required by coupled surface physiology/atmosphere models. In order to follow the surface energy budget during the dry–down period with associated rapid shifts in surface–latent to surface–sensible heat rate, the earth's surface should be viewed at least twice daily (pre–dawn and mid afternoon) for each clear day following, for example, a midsummer continental rainstorm.

Ocean Measurements

The primary research objectives requiring visible and infrared observations of the oceans relate to the need for better understanding of coastal and oceanic biological and physical processes.

The abundance and distribution of marine phytoplankton are specifically related to understanding the structure and function of marine food webs, the oceanic production of trace gases important to the earth radiation budget, and the oceanic components of the global carbon cycle.

Other research areas which require visible and near–infrared observations include: abundance and distribution of marine detritus and sediments, surface current characterizations and flow visualizations, light attenuation characteristics affecting growth and carbon assimilation of marine phytoplankton and submerged aquatic vegetation, fisheries recruitment and science, and distribution of sea surface temperature for heat flux studies.

Regional coverage at high spatial and temporal resolutions, both achievable from geosynchronous orbit, are important for investigating many of the above processes on regional scales. They are essential for addressing numerous problems in coastal, estuarine, and freshwater environments.

Coastal and Estuarine Region Measurements

Many of the distributions in the coastal and estuarine regions are determined by tidal motions which, with a 6.25 or 12.5 hour period, are not sampled frequently enough by instruments having a maximum of once or twice per day coverage. Tidal excursions (the distance traveled in one half a tidal cycle) are on the order of 5–20km. Variations in tidal current velocities result in horizontal length scales (of actively produced spatial variations) of a few meters to several hundred meters. A convenient scaling for changes in these distributions is roughly the maximum tidal current speed, which generally falls within the range of 0.2–1.5 m/sec (0.7–6.0 km/h). Thus, if the effects of tidal motions are to be accounted for in understanding patterns in remote sensing imagery, sampling frequencies of one hour or less are required. The horizontal spatial scales for these distributions are more complex and depend on water (tidal) current patterns, bathymetry, coastline shape and configuration, and related changes in biological rate processes. In the areas of interest, however, spatial scales are much shorter in the coastal estuarine regimes than in the open ocean, and resolutions on the order of a hundred to a few hundred meters are needed.

Time scales for temporal changes of water properties in the coastal and estuarine regions are dominated by daily and tidal periods. In order to resolve changes in distributions of properties due to these factors, the distributions must be sampled more frequently than every six hours. Examples of distributions which are dominated by tidal frequencies are tidal plumes of suspended sediments, red tides, other phytoplankton, and dissolved organic matter. Mobile plankton within the coastal zone and estuaries commonly undergo pronounced light–dependent vertical migration (either aggregating at the surface during daylight or at night), potentially producing large changes in remotely sensed concentrations at any given place. Separating these temporal variations from current and tidal current–induced location changes demands that both temporal requirements for coverage and frequency and spatial resolution requirements be met simultaneously.

The capability provided by a GEO sensor is thus highly complementary to the planned coverage provided by sensors on polar orbiting platforms in sampling frequency and in resolution for wide field of view (FOV) sensors. Fixed time of day coverage from polar platform sensors does not meet the basic Nyquist sampling criterion for either daily or tidal frequencies, and, therefore, global data from only a polar orbiting sensor will suffer from aliasing at tidal and daily periods. This can result in very misleading temporal and spatial distribution patterns of water bio–optical properties.

NASA GEOPLATFORM MISSIONS

The platform series now under development at NASA's Marshall Space Flight Center (MSFC) is an integral part of the MPE program, a complement to EOS platform missions, and intended to advance "...the understanding of the entire earth system on a global scale..." (Koczor et al., 1990). A key purpose of the geoplatform missions is research concerning physical processes related to the earth sciences. These processes include: mesoscale circulations–atmospheric and oceanic, precipitation and lightning, coastal processes including tides, environmental pollution, volcanic eruptions and earthquakes, marine phytoplankton blooms, water vapor sources, sinks, and structure, solar effects on the earth, atmospheric trace gases, diurnal land ecosystem processes, cloud dynamics including severe storms, and earth radiation balance. All are processes uniquely measurable from GEO.

The platforms are expected to accommodate facility, research, and possibly some precursor operational instruments. A constellation of perhaps five of these, now referred to as Geostationary Earth Observatories, is anticipated to be international in character with estimates of three U.S. Geo systems and two derived from other countries. International participation is envisioned for the full constellation in terms of sensor complements and data usage. Launch dates in the early 2000s have been mentioned. A more definite date will evolve after a NASA "new start" is authorized.

A strawman list of thirteen candidate instruments was presented by Koczor et al. (1990) at the fifth Conference on Satellite Meteorology and Oceanography in London, England on 3–7 September 1990. The list is, of course, subject to change as the study proceeds due to spacecraft and other technological limitations or scientific requirements. Instrument numbers F1, F2, F3, F4 and F5 listed below have been designated strawman "facility" instruments designed to provide multi–disciplinary observations and obtain data to complement low altitude earth information derived from Landsat, EOS, the NOAA weather satellites, and other missions deployed in space. Some of the instruments listed (numbers O4, O5, O6, O7, O8, O9 and O10) were selected as strawman candidates for the geoplatform to support operational requirements for terrestrial, oceanic, atmospheric, and solar measurements. Information of the type obtained from these instruments is currently being provided by or planned for the NOAA GOES series. Measurements not yet available from low altitude orbits, or previously not obtained from geostationary orbits, are expected from Principal Investigator (PI) strawman instrument numbers PI11, PI12, and PI13.

FACILITY INSTRUMENTS

F 1	Geostationary Microwave Precipitation Radiometer (GMPR)
F 2	Geostationary Atmospheric Profiler (GAP)
F 3	Geostationary Earth Processes Spectrometer (GEPS)
F 4	Advanced Lightning Mapper (ALM)
F 5	High–resolution Earth Processes Imager (HEPI)

OPERATIONAL INSTRUMENTS

O 6	Geostationary Operational Imager (GOI)
O 7	Geostationary Operational Sounder (GOS)
O 8	Space Environment Monitor (SEM)
O 9	Solar X–ray Imager (SXI)
O 10	Geostationary Data Collection Platform (GDCP)

PRINCIPAL INVESTIGATOR INSTRUMENTS

PI11	Solar Total Irradiance Monitor (STIM)
PI12	Solar Spectral/Irradiance Monitor (SSIM)
PI13	Geostationary Earth Climate Sensor (GECS)

MSFC has been assigned as the lead center for the Geostationary Earth Observatories program and is developing platform designs and conducting Phase–A studies of the candidate instruments. Designs have been evolving as science requirements and corresponding instrument complements are refined.

Instrument sizes range from 0.3 – 4.4m length, 0.3 – 4.0m width, and 0.2 – 1.4m height. Instrument power requirements range from 10 to 300W totaling approximately 1400W. Data rates per instrument vary from 1 to almost 13,000kbps with a total data rate of approximately 28mbps. The thirteen instruments collectively weigh over 1900kg including 30 percent contingency. An earlier 1989 report from the same source indicates a total platform to payload weight ratio of about 2.84 including on–board propellant which would require a Titan IV Centaur launch vehicle. Overall platform weight is about 5400kg which includes a 2500kg bus, 1900kg of sensors, and 1000kg of propellant. This weight estimate is applicable to the in–house geoplatform concept and is subject to change. The studies have carefully taken into account the strict orbital attitude control system requirements of space imagers and sounders in GEO for earth measurements.

When the missions are deployed in orbit they will be the largest ocean, land and atmospheric unmanned space mission in GEO, meeting many user requirements for expanded remote sensing capabilities from space. With the EOS in LEO, the combination of the two platform systems will constitute an impressive array of inter–related earth science sensors.

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